AD-A193 061 A MODEL FOR VISUAL ATTENTION(U) NORTHEASTERN UNIV BOSTON MA A REEVES 01 APR 88 AFOSR-TR-88-0485 AFOSR-87-0172 1/1

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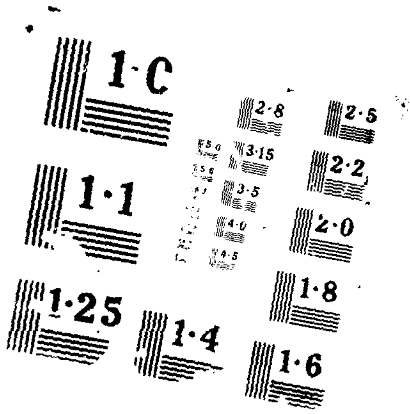

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REPORT DOCUMENTATION PAGE

AD-A193 061

DTIC FILE COPY

1b. RESTRICTIVE MARKINGS	
3. DISTRIBUTION/AVAILABILITY OF REPORT	Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	
5. MONITORING ORGANIZATION REPORT NUMBER(S)	AFOSR-TR- 88-0485
6a. NAME OF PERFORMING ORGANIZATION	Northeastern University
6b. OFFICE SYMBOL (If applicable)	
7a. NAME OF MONITORING ORGANIZATION	AFOSR/NL
6c. ADDRESS (City, State, and ZIP Code)	360 Huntingdon Ave, Boston Mass 02115
7b. ADDRESS (City, State, and ZIP Code)	Building 410, Bolling AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	AFOSR / NL
8b. OFFICE SYMBOL (If applicable)	NL
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	AFOSR-87-0172
8c. ADDRESS (City, State, and ZIP Code)	Building 410, Bolling AFB, Wash. DC 20332-6448

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61102F	2313	A5	

11. TITLE (Include Security Classification)
A model for visual attention

12. PERSONAL AUTHOR(S)
Adam Reeves

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical	FROM 3/87 TO 3/88	1 Apr 1988	6

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Research has been undertaken on visual attention and short-term visual memory (VSTM). One set of experiments has concerned the role that depth information might play in retrieval from VSTM, using an iconic memory paradigm. Another set concerns development of the attention-gating model, using the attention-shift RSVP paradigm. Finally, we are studying some effects of attention and visual imagery on visual acuity.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS
21. ABSTRACT SECURITY CLASSIFICATION	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL	John Tangney
22b. TELEPHONE (Include Area Code)	202 767 4278
22c. OFFICE SYMBOL	NL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

12 APR 1988

AFOSR-TR- 88-0485

Grant AFOSR-87-0172 file:af.txt

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Technical Report: first year (3/87 to 3/88)

Summary.
Research has been undertaken on visual attention and short-term visual memory (VSTM). One set of experiments has concerned the role that depth information might play in retrieval from VSTM, using an iconic memory paradigm. Another set concerns development of the attention-gating model, using the attention-shift RSVP paradigm. Finally, we are studying some effects of attention and visual imagery on visual acuity.

(A) Visual attention and depth.
Work with Dr. Charles Tijus of University of Paris 8, who is visiting here (Oct 88 to Sept 89) as a Post-doc, has concentrated on the relevant of depth information for visual memory. Previous work in visual memory has typically employed 2-D arrangements of letters and numerals. Our work is directed towards finding out whether providing depth cues will enhance performance. The work is essentially exploratory.

Depth is manipulated in two ways; by providing perspective, and by providing stereo. In the perspective arrangement, letters designed to appear further away are drawn smaller than, and above, those designed to appear close up. Fixation is requested just above the top row of smaller characters, so that the smallest letters are presented closest to the fovea where acuity is highest. In this way accuracy of report does not vary too much with the row being probed. In the stereo arrangement, the subject views the screen through a prism arrangement in front of the left eye. Cardboard masks direct the left half of the screen to the left eye, and the right half of the screen to the right eye. The subject rotates the prism so as to align the two images. The depth of each row is specified by varying the relative disparity of the row. All the letters are the same size in the 'stereo alone' condition, and the subject fixates the center of the display. In the perspective+stereo arrangement, both perspective and stereo is provided, and fixation is again at the top. In these experiments, letters appear to be in different depth planes in different rows, but letters do not overlap. Arrangements in which letters are viewed 'through' each other are also planned.
In the final, standard condition, the display is flat (without stereo) and the letters are all the same size. Fixation is central.

Visual memory is tested in several ways. In the search task, the subject must search the stimulus array for a single target. In the partial-report task, the subject will be asked to report all items in a row. The identity of the target or of the row is either known before the trial, or revealed only after the display has been presented. The array either contains same-category (e.g., letter-letter) or different category (eg, letter-numeral) distracting characters. Each task is crossed with the four depth conditions.

The purpose of the variation of category is to establish whether Sperling's original (1960) result, that VIS is pre-categorical, is really correct. In Sperling's work, subjects were asked to write down items that

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were either all in the same row (standard condition), or were in perhaps different rows but belonged to the same category. The difficulty that subjects had in picking by category was used to infer that VIS was essentially visual (ie, precategorical); or, to put it another way, that one could only direct one's attention to a part of the remembered array which was specified by location. However, the difficulty might have arisen from the task of having to report items that were in fact in different rows, and thus less easy to organize for report. In the search task, the subject merely has to report whether a target is in the display, and its location; this task is exactly the same whether the target belongs to the same category as the distractors or not. In the partial report task, the subject reports the items without being asked to specify their location, so that report organization will not be a factor.

Results with nine naive subjects in the search task show that both perspective and stereo cues help performance. A long-term study with three subjects has shown that the effect of stereo is quite constant over 12 sessions, producing an improvement of about 10% in accuracy of report of location, but that the effect of perspective increases with practice to about 16%. When both cues are provided, it seems that the stronger one wins; that is, the improvement obtained with both cues is roughly equally to the greater of the two improvements measured separately.

The effect of stereo is easier to interpret in these experiments as a pure depth effect, because the spatial structure of the stimuli (letter size and spacing) is the same with and without stereo. This is not so with the letters in perspective, however. A 'flat' control for perspective, using the same set of letter sizes as in the perspective case, but assigning them at random to location, was therefore run. In the control, the array did indeed appear flat, but the large letters tended to laterally mask the smaller letters and so the comparison was vitiated. A new control, in which the local surroundings of characters in the middle of the display is balanced in the perspective and flat conditions, is planned.

Results concerning the category effect are so far incomplete. With the partial report method, performance dropped about 10% when the target was in the same category as the distractors (3 subjects). However, preliminary indications are that category does not affect search for a single target.

(B) Attention-shift RSVP

The purpose of the research is to study the effects of shifting attention on the perception of a stream of characters in RSVP (rapid serial visual presentation). In the 'attention-shift paradigm' being used, a subject moves his attention from one visual display (say, left of fixation) to a second RSVP display (say, at the right). The timing of the attention shift is controlled by the characteristics of the first display. The effect of the attention shift on the perception of the second RSVP display is studied by requiring a subject to report characters from his short-term memory of the RSVP display. The characters used in the RSVP display are letters, numerals, or easily-codable outline geometric forms, which are presented in a stream, one after another, to the same location in the visual field. The main finding has been that the attention shift produces a remarkable temporal order illusion; subjects report seeing the RSVP characters in an order different from their presentation order. For example, typically the fourth character after the attention-shift cue may be seen as occurring first; the third, as next; then the fifth, then the second; and so on. A three parameter 'attention-gating model' (AGM) can capture not only the typical order, but also trial-to-trial variability in the order (Reeves and Sperling, 1986). The current work involves further testing and extending the AGM, by testing the effects of memory load, of item category, of frame size (one or two characters), and eye movements.

Memory load

In developing the AGM, we assumed that attention operated to gate the entry of characters from the RSVP display into short-term visual memory; once in memory, the order of the characters was unchanged. The 'action' in the model stems from the bell-shaped time course of the attention shift, first towards, and then away from, the RSVP display. Characters occurring at the peak of the bell receive maximum attention and tend to be reported as seen first; both earlier- and later- characters receive less attention and tend to be seen as later. (falsely, in the case of earlier characters). However, in an important theoretical paper, Grossberg and Stone (1986) showed that a model in which the attention gate was virtually box-car shaped, but assumed internal competitive processes within VSTM, could also account for the results. They termed this the TOI (temporal order information) model.

One way in which the models may be compared is in terms of their predictions for the effects of memory load. Three subjects have been run in an experiment in which, for many blocks of trials, either two, or four, or six characters must be reported on each trial. The first question was whether the data of the first two reports would be the same in the three report tasks, a model-free comparison. The second question is whether parameters derived from the standard recall-4 case could accurately predict all the remaining data. The answers bear on the comparison of AGM with TOI, because as the models make different predictions. In the TOI, the strengths of the first two items in VSTM should depend on the number of succeeding items, because each incoming item tends to compete with resources allocated to the earlier items. As the strengths are the main factors determining perceived order, the TOI predicts more order confusion within the first two recalls as the memory load is increased. However, the AGM predicts independence of memory load because the time-course of the bell-like attention shift in AGM is determined by the first display, not by the second RSVP display. Similarly, the parameters derived from recall 4 should predict recall 2 and recall 6 data according to the AGM; this is not so in TOI. Thus, independence of memory load in both experimental tests would favor AGM over TOI.

The results of this test support AGM. The model-free comparison showed no systematic variation of percent order error with recall load, as reported in the first 6-month period and confirmed on a third subject. The model-dependent fits also support the AGM prediction that the attention curve should not depend on recall load. As reported, the three best-fitting AGM parameters (alpha, tau, and sigma) account for about 87% of the variance when fixed for each subject across recall load. The very best any one-dimensional precedence model can do (the Case-V solution in Reeves and Sperling, 1986, with every precedence strength in every condition allowed to vary freely) averages to 94% of the variance, so the very constrained AGM does well against this upper limit. (Moreover, the residual variability appears so far to be little related to recall load.) Data from the final subject has not changed this picture.

Item category

A second line of attack on the comparison of AGM with TOI, concerns the nature of the items entered into VSTM. The AGM cannot discriminate between items, at it is 'pre-categorical'; that is, the gate simply operates to permit as-yet-unidentified items to flow into VSTM. However, in TOI items compete inside a memory which is already structured by resonant feedback, so that items within the same class (in long-term memory) should compete more than those in different classes. An experiment has been developed to compare the models by interjecting infrequent 'other-category', or 'odd', stimuli into the RSVP stream. So far, data have been collected using a numeral stream with the odd characters being Landolt C's of different orientations. It has already been shown that with the C's, recalls fit the AGM about as well as with numerals (Reeves, 1987). For one subject (AR), the set of C's is well learnt, but has never been visually presented with the set of numerals. This subject has learnt a coding scheme for reporting C's (pressing the key-pad in the orientation of the gap) which has become easy and automatic to use. The preliminary results appear to support the AGM, because the 'odd' characters seem to enter VSTM in the same way as do the numerals. (Since 'odd' characters and numerals are not visual equivalent, a direct comparison of order accuracy on trials with and without odd characters is not quite appropriate. Rather, the comparison is made between reports of numerals from the first n-1 stimulus positions in trials without odd characters and in trials with, given that the odd character appeared in position n.)

This is a weak result, in that TOI is not committed to stating the numerals and C's must be in different classes. On the other hand, finding a difference due to the odd character would be a direct blow to AGM, and support TOI. I therefore plan to continue with this line of experiment, and try to find other cases in which the evidence may favor the TOI. My interest is not merely in testing the two models, but in establishing whether the VSTM assumed by both models can indeed be treated as 'pre-categorical' (as in the iconic memory experiments).

Frame size (single or paired characters)

Another line of work planned in the grant concerns the size of the RSVP display. This work will become possible now that the new visual display hardware (for rapid point plotting) has been received.

Attention and eye movements

A different line of work concerns the comparison of attention shifts with and without saccadic eye movements. The main finding (with the eye-tracker) is that there is little difference in attention-shift latency or in order confusions when eye movements were required along with the attention shift, as compared to eyes still. In a further test, the subject is required to shift attention to the RSVP display at the same time that he executes a saccade in the opposite direction. Two subjects have now been practiced over many thousands of trials. The task is remarkably difficult, but is now accomplished on about 40% (one subject) or 55% (the other) of trials, in that the saccade is executed in the appropriate time frame (from .1 sec after the cue to 1 sec after the cue); the saccade is accurate to 20% of the distance between the RSVP streams; and that a numeral report is obtained with above zero confidence. One most of the trials in which an opposite-direction saccade is accomplished, the attention shift is delayed, and the order information is systematically distorted as seen in the standard, no eye-movement case. However, there are some trials in which both movements appear to occur together; in these cases the order information seems to be further scrambled. I propose to run the subjects in yet further sessions in order to collect of these latter types of trials (if indeed the distinction turns out to be really warranted), because it is of considerable interest to discover whether attention shifts and saccades can become independent of each other after sufficient learning.

(C) Attention, acuity, and the 'Perky effect'.

A final line of work has been undertaken by the PI and by Catherine Lemley, who was supported by the prior grant and has been supported part-time on this grant. She has studied the effects of manipulating two cognitive variables, attention and visual imagery, on visual acuity. The first paper, on visual imagery effects, is (still) in press with Perception. In further work, we have discovered a complex interaction between imagery and attention. In one manipulation, in which attention is distracted from the acuity task by a winking light which must be monitored, the normal effect of imagery in reducing acuity (the 'Perky' effect) is virtually eliminated. However, when attention is manipulated by requiring attention to either one, or two, possible target locations in each trial block, attention and imagery have independent effects on acuity. Since we had no reason to expect that these two different ways of manipulating attention would yield different results, we have been pursuing an investigation of these issues. We have established that retinal location (foveal versus parafoveal) and stimulus duration, both of which had differed across the two original attention experiments, do not account for the difference in the results.

EQUIPMENT

A custom-built high-speed point plotter has been obtained from Gary Finlay at the University of Alberta. This plotter is specifically designed for the computer system (PDP 11) and display (Hewlet Packard 1332) that I use. It increases plotting speed by a factor of 20, and so provides a major upgrade, allowing experiments with many more characters or with more complex displays. Software, including a driver, has been developed for the PDP/11- plotter combination by Terry Caelli of the Psychology Dept., University of Alberta. Caelli has donated this software free of charge.

Disk. The Winchester disk and controller for the 11/23 system (used for the attention-shift experiments) I had originally budgeted at $4,840 was obtained for much less ($ 2475 from CDC and DILOG). Installing this combination turned out to be a problem, since the power requirements were larger on +12 volts than supplied by the DEC system, and then because even when installed, the disk/controller intermittently takes 14 seconds (!) to perform an access. An engineer at DILOG is now trying to run this problem down. Thus, although research went well in the first 9 to 10 months of the grant, it has recently been stalled by computer malfunctions. Research on the 11/73 has been set back by 10 weeks (so far) by a power supply failure which blew the processor card and some of the image processing cards; the former card has been repaired but the latter cards are still being worked on by the manufacturer (ITI). Repairs of both systems have had to be charged to the grant, but testing the cards here and re-installation has been done by technical staff paid for by the University.

PERSONNEL

Graduate Research Assistant. During the summer, I supported Chisato Aoki on the grant.

From Oct 1, I have supported Charles Albert Tijus as a Post-Doc. He has a doctoral degree (troisieme cycle), but is aiming for the higher Doctor D'etat degree from the University of Paris. He has received additional support from a Lavoisier grant to bring his total income up to Post-Doc levels. I have been paying him standard doctoral level student stipend.

TRAVEL.

I spent one week (Aug 10-15) in Edmonton with Terry Caelli and Walter Bischof, learning their software system for DEC 11/23 -HP plotter controller combination. I have also obtained and learnt some other software, for our 11/73-Purkinje tracker equipment.

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